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Patent Application of

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For

**PACKAGING OF SEMICONDUCTOR DEVICES FOR
INCREASED RELIABILITY**

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**PACKAGING OF SEMICONDUCTOR DEVICES FOR
INCREASED RELIABILITY**

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Background of Invention

Field of the Invention

10 The present invention relates generally to
integrated circuits. More specifically, but without
limitation thereto, the present invention relates to
packaging of integrated circuits for high-reliability,
including, for example, shielding of the integrated
15 circuits from radiation, such as ionizing radiation.

Discussion of the Background Art

 Various applications in which integrated circuit
20 devices are employed place demands on the integrated
circuit devices not typically present in consumer
applications. For example, in space satellite applications,
ionizing radiation is present in the space environment at
levels that often results in an integrated circuit die
25 being exposed to an amount of radiation in excess of the
integrated circuit die's total dose tolerance. As a result,
the integrated circuit die can become damaged, or perform
improperly, such as drifts in parametric performance or
loss of functionality. Thus, the integrated circuit device
30 may become unreliable.

 Furthermore, excess heat buildup within the
integrated circuit device can result in the integrated

circuit die operating at a temperature in excess of its
temperature operating range, in turn potentially resulting
in damage to the integrated circuit die, or unreliable
performance of the integrated circuit due, such as by the
5 generation of errors

At the same time, integrated circuit devices that
are sent into space must be robust enough to survive the
launch of a spacecraft from earth, deployment in space, and
10 potentially some amount of impact-related trauma once
deployed. As a result, not only must an integrated circuit
device used in space provide or be used in conjunction with
a mechanism for preventing the exposure of the integrated
circuit die to ionizing radiation in excess of its total
15 dose tolerance, and provide or be used in conjunction with
a mechanism for maintaining the temperature of the
integrated circuit die within its temperature operating
range, while at the same time maintaining or increasing the
mechanical robustness of the integrated circuit package.

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Another important aspect of integrated circuit
devices that are sent into space is that such integrated
circuit devices must be light weight enough to meet weight
constraints inherent in integrated circuit devices that are
25 launched from earth to space, e.g., earth orbit. Thus, in
addressing the need for a mechanism for preventing the
exposure of the integrated circuit due to ionizing
radiation in excess of its total dose tolerance and the
need for a mechanism for maintaining the temperature of the
30 integrated circuit due within its operating range, and the
requirement for mechanical robustness, the integrated

circuit device for use in a space environment must be light weight.

Accordingly, in many radiation environments

5 integrated circuit die must be shielded from radiation in order to function reliably. For example, as mentioned above, in a space environment, integrated circuit die must be, for example, shielded from ionizing radiation or the circuit may fail to function reliably. Additionally, the

10 integrated circuit die may need to be shielded from, e.g., x-rays that can damage the circuit die, thus, causing it to fail or function unreliably. In a space environment, servicing, e.g., replacing a part that has failed or otherwise become unreliable is extremely expensive or all-

15 together impossible. Thus, an integrated circuit die to be used in a space environment should shielded from one or both of ionizing radiation and x-ray radiation in order to function reliably.

20 Always, when packaging integrated circuit die for use in a high radiation environment such as space, the size and weight of the package is a major concern both due to weight limitations inherent in a space launch and relationship between weight and inertial mechanical forces

25 to which the electronic circuit device will be subjected. Thus, an integrated circuit device that is very bulky or heavy adds not only cost to the launch of the systems in which the integrated circuit device is used, but, perhaps more importantly, reduces the reliability of the integrated

30 circuit device. For example, the integrated circuit device may become unreliable because the weight of the part results in more stress on solder joints within the

integrated circuit device, such as solder joints that connect the integrated circuit device to the circuit board, or solder joints that affix the lid of the integrated circuit device package. Thus, a reduction in the weight of an integrated circuit device benefits the integrated circuit device not only in making it lighter, and thus reducing the weight of the system, but results in less stress on the solder joints, and thus increases the reliability of the integrated circuit device, and the system in which the integrated circuit device is employed.

Heretofore, multi-chip modules provided integrated circuit devices comprising a package, and multiple integrated circuit die within a single-layered integrated circuit device package. The multi-chip module needs enough shielding material, either in its package, externally, or both, to shield the most sensitive of the multiple integrated circuit die within the multi-chip module, in order to assure the reliability of the most sensitive integrated circuit die within the multi-chip module. The amount of shielding material necessary to effect this amount of shielding, results not only in an unacceptably high weight, but an unacceptably high cost, as elaborated upon below.

Additionally, the amount of external shielding material in a multi-chip module (or a single-chip integrated circuit device), particularly when the integrated circuit device is designed for sensitive integrated circuit die and/or harsh space environments, greatly reduces the consistency with which a hermetic seal between the lid of the integrated circuit package and the

sidewalls or base of the integrated circuit package. As the amount, e.g., thickness, of the shielding material required becomes greater, the ability of manufacturing processes to achieve a hermetic seal between the lid and the sidewalls or base is becomes less. This is because the shielding material, in addition to providing shielding of the integrated circuit dice within the multi-chip module (or single-chip integrated circuit device), acts as a heat sink, thus affecting the soldering process used to achieve a hermetic seal between the lid and the sidewalls or base. A hermetic seal between the lid and sidewalls or base is important, however, as such hermetic seal keeps moisture and other chemical contaminants from infiltrating the integrated circuit device, and causing deterioration of the integrated circuit dice, thus causing failure of the integrated circuit device or a reduction in the reliability of the integrated circuit device.

The ability to obtain a hermetic seal also decreases as the size of the integrated circuit device package increases. Both the shielding material, such as may be used in the lid, and the material used for the sidewalls and/or base of the integrated circuit device package expand and contract in response to thermal variations at certain rates depending upon the materials employed. As the length of the seal between the lid and the sidewalls or base increases, the amount of the difference between the amounts of the expansion or contraction in response to thermal variations of the lid verses the sidewalls or base increases. This results in warping at the interface between the lid and the sidewalls or base, which, in turn, decreases the ability of manufacturing processes to obtain

a hermetic seal because the stress and strain at such interfaces increases. As described above, this inability to achieve a lack of hermeticity is undesirable.

5 As will be readily appreciated by one of ordinary skill in the art, the problems described above, while attributed to integrated circuit devices designed for use in space environments, are present in other environments as well. Thus, the embodiments described below will be
10 appreciated as having numerous applications beyond space applications. For example, thermal (heat) dissipation is a significant issue in high-volume, high-density devices. The embodiments described herein provide a significant improvement to heretofore known devices with respect to
15 thermal dissipation.

 Specifically, as the need for large amounts of memory, and other high-volume integrated circuit devices, has increased with the increase in complexity, processing
20 capacity and processor bits, the need for compact memory storage devices, and other high-volume and high-density integrated circuit devices, has increased. Large amounts of circuitry, such as high-volume memory modules, produce large amounts of heat that can ultimately cause the high-
25 volume memory modules to fail or otherwise become unreliable. Prior approaches to packaging high-volume, high-density memory modules involve stacking multiple memory chips in plastic packages on top of one another. Traditional plastic packaging of the memory chips does not
30 provide enough heat dissipation for a high-reliability high-volume, high-density memory module. The lack of an ability to adequately dissipate heat leads to larger

integrated circuit devices and less circuit density.
Furthermore, the lack of ability to dissipate heat leads to
increased integrated circuit device failure or
unreliability.

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Thus there is a need for improved integrated circuit
devices and methods to address the numerous problems
articulated above, as well as others.

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Summary of Invention

In various embodiments, the present invention
advantageously addresses needs articulated above as well as
other needs by providing a highly reliable multi-layered
integrated circuit device.

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In one embodiment, the present invention includes a
radiation shielding integrated circuit device comprising a
plurality of package layers comprising a circuit package; a
radiation shielding base coupled to the circuit package;
20 and a circuit die coupled to the radiation shielding base;
a radiation shielding lid coupled to the plurality of
package layers; and a plurality of pin connectors; wherein
the circuit die are shielded from receiving an amount of
radiation greater than the total dose tolerance of the
25 circuit die; wherein the plurality of package layers are
stacked on top of each other such that a bottom of a first
package layer acts as a top of a second package layer.

In another embodiment, the invention can be
30 characterized as a radiation shielding integrated circuit
device comprising a plurality of package layers comprising

a circuit package; a radiation shielding lid coupled to the circuit package; and a circuit die coupled to the circuit package; a radiation shielding base coupled to the plurality of package layers; and a plurality of pin
5 connectors; wherein the circuit die are shielded from receiving an amount of radiation greater than the total dose tolerance of the circuit die; wherein the plurality of package layers are stacked on top of each other.

10 In yet another embodiment, the invention advantageously includes a method of shielding an integrated circuit device comprising forming a first package layer comprising a first radiation shielding base, a first circuit package and a first circuit die; forming a second
15 package layer comprising a second radiation shielding base, a second circuit package and a second circuit die; coupling a bottom of the first package layer to a top of the second package layer; and coupling a lid to the first package layer.

Brief Description of Drawings

20 The present invention is illustrated by way of example and not limitation in the accompanying figures, in which like references indicate similar elements, and in
25 which:

Fig. 1 illustrates a shielding package separated into layers designed to shield a plurality of electronic circuit die from radiation;

Fig. 2 illustrates the shielding package of Fig. 1
after the layers have been assembled;

Fig. 3 is a flow chart showing a method of
5 determining an amount of shielding needed for a layered
shielding package in accordance with the present invention;

Fig. 4 illustrates a layered shielding package
designed to shield from radiation a plurality of electronic
10 circuit die mounted directly to a ceramic package

Fig. 5 illustrates a layered shielding package
designed to shield from radiation a plurality of electronic
circuit die mounted directly to a shielding layer;
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Fig. 6 illustrates a layered shielding package
designed to shield from radiation a plurality of electronic
circuit die mounted directly to a substrate;

20 Fig. 7 illustrates a layered shielding package
designed to shield from radiation a plurality of electronic
circuit die mounted directly to a substrate;

Fig. 8 illustrates a layered shielding package
25 designed to shield from radiation a plurality of electronic
circuit die mounted directly to a substrate;

Fig. 9 illustrates a package for dissipating heat
from a plurality of circuit die; and
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Fig. 10 is a flow chart showing a method of making a highly reliable layered electronic circuit device in accordance with the present invention.

5 Skilled artisans will appreciate that elements in the figures are illustrated for simplicity and clarity and have not necessarily been drawn to scale. For example, the dimensions of some of the elements in the figures may be exaggerated relative to other elements to help to improve
10 understanding of embodiments of the present invention.

Detailed Description

Advantageously, the present invention, in various embodiments, provides for a high-reliability integrated
15 circuit device and integrated circuit device package therefore. The present embodiments provide an integrated circuit device package that protects integrated circuit die within the integrated circuit device package from at least one of: ionizing radiation, x-ray radiation, mechanical
20 forces, thermal failure, and chemical contaminates. Additionally, the various embodiments can provide for a high-reliability integrated circuit device package that has high manufacturing yields.

25 In some embodiments, the present invention provides for a radiation shielding device and method that protects a plurality of integrated circuit die from radiation found in a space environment. Radiation that comes into contact with an integrated circuit die can cause the integrated
30 circuit die to fail or otherwise become unreliable. The radiation shielding shields the plurality of integrated

circuit die from receiving an amount of radiation greater than the total dose tolerances of each of the plurality of integrated circuit die within the integrated circuit device package. In some embodiments, a higher amount of shielding
5 will be required for some of the plurality of integrated circuit die as compared to other integrated circuit die within the same integrated circuit device package.

Advantageously, the present embodiments provide for a an integrated circuit device package with multiple shielding
10 layers, wherein the integrated circuit dice that require a relatively larger amount of shielding as compared to other integrated circuit die within the package, when placed nearer to a center of the integrated circuit package, have multiple shielding layers protecting such integrated
15 circuit dice from radiation. This provides for a highly reliable integrated circuit device package that protects a plurality of integrated circuit die from an amount of radiation greater than the total dose tolerances of each of the plurality of integrated circuit dice, while at the same
20 time not paying the weight or size (footprint) "price" of heretofore known approaches. Because each of the integrated circuit die are protected from an amount of radiation greater than each of their total dose tolerances, the integrated circuit device is highly reliable in
25 radiation environments, e.g., a space environment.

In other embodiments, the present invention provides for an integrated circuit device package and method that incorporates integrated circuit die that produce large
30 amounts of heat. Advantageously, the integrated circuit device package of these embodiments serves as a heat sink, thus preventing the integrated circuit die from failure or

otherwise becoming unreliable due to high operating temperatures. Generally, the high temperatures are caused by the integrated circuit die themselves, however, outside temperatures may also contribute to the high temperatures.

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Advantageously, the present embodiments, provide for a high-volume, high-density memory module that can dissipate the heat generated by the integrated circuit die, e.g., a large amount of memory. The present embodiment is able to dissipate the heat by using at least one of a lid and a base of the integrated circuit device package as a thermal conductor. The present embodiments are able to dissipate large amounts of heat while taking up relatively little space on a circuit board as compared to other multi-layered devices.

Multi-layered devices generally are a group of integrated circuits packaged in a plastic packaging that have been stacked on top of each other and sold as, e.g., a memory module. Because the plastic casing is not efficient as a heat sink, in order for these packages to effectively dissipate heat, a relatively larger amount of thermal conductor is needed as compared to the present embodiments. In the present embodiments, the lid and/or base are made from a thermally conductive material. Thus, the thermally conductive base and/or lid present not only at the top and/or bottom of the integrated circuit device package, but also between each layer (or at least between two of the layers) of the integrated circuit device. As a result, heat dissipates through the thermal conductor not only from above and below the integrated device package, but also from between layers of the integrated circuit device.

Thus, the thermally conductive base and/or lid allow for a large amount of heat dissipation as compared to a memory modules encased in plastic packaging, and thus less thermal conductor is needed to dissipate heat allowing for
5 a lighter, more compact multi-layered device.

Another advantage of a more compact multi-layered device is that it provides for an increased circuit density. Increased circuit density is desirable as a
10 circuit device with very short traces generally performs more quickly and reliably than a device with longer traces or with more discrete components connected with traces on a printed circuit board. The shorter the traces are, the less electromagnetic coupling and the less likelihood there
15 will be a problem with the circuit trace. Thus, because the more compact multi-layered device of the present embodiments enables the use of shorter traces, the multi-layered device of the present embodiments is more reliable than prior devices.

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Advantageously, the present embodiments provide high heat dissipation while reducing the size and weight of the package as compared to a single layered package containing the same amount of memory. By stacking the
25 layers, the size of both the lid and the base are greatly reduced. This is because the integrated circuit die are located above one another rather than adjacent to one another or side by side, thus taking up a smaller area and allowing for a smaller lid and base. The reduction in size
30 also provides for great weight savings as in some embodiments the lid and the base are very dense material, thus, a reduction in the area of material used corresponds

to a large amount of weight reduction. This provides for a smaller device while still having enough thermally conducting material used for the lid and/or base to effectively dissipate heat. In some embodiments, each
5 layer of the device is connected through thermal vias (thermally conductive connections) to the lid and/or base, which allows for proper heat dissipation of all of the layers of the integrated circuit device package. In further embodiments, the integrated circuit device is also
10 thermally connected to a board-level heat sink or system heat sink to allow further heat dissipation. Thus, the present embodiments advantageously provide for a memory module that can dissipate heat while greatly reducing the volume of the package and/or the area of the package
15 (footprint) as compared to a single layer package containing the same amount of memory. In one preferred embodiment, the lid and/or base are made from Copper-Tungsten. In general the amount of copper tungsten needed for radiation shielding satisfies the heat dissipating
20 requirements

Advantageously, the integrated circuit device package of the present embodiments also has better manufacturing yields than single layer prior art package
25 designs designed to hold a comparable amount of memory. One major contributor to the manufacturing yields is the ability to achieve a hermetic seal between the lid and the sidewalls or base or the integrated circuit package. The ability to achieve a hermetic seal is exponentially related
30 to length of the seal. This is because the interface between the materials used for the lid and the sidewalls or base warps at a certain rate depending upon the materials

used. At a certain point, there is too much warping, and the integrity of the solder at the interface fails under the forces causing such warping. As a result, the hermeticity of the interface is compromised. (This is also
5 due to the materials not being able to lay flush against one another during the soldering process.) A single layered device having the same amount of memory as the embodiments described herein has a larger lid, i.e., lid with longer sides, than the lid of the present embodiments.
10 Thus, the lid of the single layer device is more likely to have an amount of warping that will result in failure due to loss of hermeticity. Thus, the device of the present embodiment more consistently forms a hermetic seal between the lid and the sidewalls or base of the integrated circuit
15 package. This increases the manufacturing yields of the embodiments described herein.

In yet other embodiments a highly reliable package design is provided to protect a plurality of
20 integrated circuit die within different layers of the package from an amount of radiation greater than a total dose tolerance of each of the plurality of integrated circuit die. In accordance with the present embodiments, the integrated circuit die on different layers of the
25 package design can have different total dose tolerances and yet be protected from an amount of radiation greater than their total dose tolerance. The integrated circuit die with the smallest total dose tolerances are placed on the inner layers (furthest from the lid and base of the
30 package) of the integrated circuit device package. This provides the more sensitive integrated circuit die with multiple layers of shielding sufficient to shield the more

sensitive integrated circuit die with shielding sufficient to prevent the more sensitive integrated circuit die from exposure to ionizing radiation in excess of the total dose tolerance of the more sensitive integrated circuit die, while at the same time not shielding all integrated circuit die, many of which do not require this same amount of shielding, to the same degree. This provides for a high-reliability integrated circuit device for housing a plurality of integrated circuit die having different total dose tolerances, and being shielded in different amounts selected as a function of such total dose tolerances. As a result, a lighter, smaller area, more hermetic, more reliable integrated circuit device is provided.

15 In accordance with the present invention an exemplary method is provided for making a highly reliable package design that protects a plurality of integrated circuit die within different layers of the package from an amount of radiation greater than a total dose tolerance of each of the plurality of integrated circuit die. First, the total dose tolerances of the plurality of circuit die are determined. Second, the position of the plurality of circuit die within the highly reliable package design is determined. Generally, the circuit die with the largest total dose tolerance will be placed on either the top and the bottom layers of the package. A lid and base will then be selected with the proper amount and type of material such that the circuit die with the largest total dose tolerance will be shielded from an amount of radiation greater than its total dose tolerance. Next, a circuit die with a smaller total dose tolerance will be placed on one of the inner layers of the package. An inner shielding

layer will then be selected taking into account the type and amount of material used for the lid and base. The amount and type of the inner shielding layer will be selected such that the circuit die with the smaller total
5 dose tolerance is shielded from an amount of radiation greater than its total dose tolerance while taking into account the other shielding layers. This process is repeated for all remaining circuit die. Generally, The more sensitive circuit die are placed on the inner layers
10 of the package such that the aggregate of all the shielding layers will provide the required amount of shielding needed to prevent the integrated circuit die failing or otherwise becoming unreliable. Thus, in accordance with the present embodiments, a method is provided for designing a package
15 for a plurality of circuit die having different, wherein some of the circuit die may have different total dose tolerances.

In accordance with the embodiments, it should be
20 understood that the package design is designed to be a high reliability part for operation, e.g., in space, military, and other high reliability consumer applications.

Referring to Fig. 1, a shielding package is shown
25 separated into layers designed to shield a plurality of electronic circuit die from radiation. Shown is the radiation shielding lid 102, the first layer 104, the second layer 106, the first shielding base 108, the second shielding base 110, the first substrate 112, the second
30 substrate 114, the first plurality of circuit die 116, the second plurality of circuit die 118, the first circuit package 120, the second circuit package 122, the first

plurality of conductors 124, the second plurality of conductors 126, and the plurality of package leads 128.

Shown in Fig. 1 is a radiation shielding lid 102, a
5 first layer 104, a second layer 106, a first shielding base 108, a second shielding base 110, a first substrate 112, a second substrate 114, a first plurality of integrated circuit die 116, a second plurality of integrated circuit die 118, a first circuit package 120, a second circuit
10 package 122, a first plurality of conductors 124, a second plurality of conductors 126, and a plurality of package leads.

The radiation shielding lid 102 is coupled to the
15 first circuit package 120 and the first shielding base 108 is also coupled to the first circuit package 120 forming a cavity for the first substrate 112 and the first plurality of circuit die 116. For the first plurality of circuit die 116 are coupled to the first substrate 112, which is
20 coupled to the first shielding base 108. The first shielding base is coupled to the second circuit package 122. The second shielding base 110 is coupled to the second circuit package 122 forming the cavity for the second substrate 114 and the second plurality of circuit
25 die 118. The second plurality of circuit die 118 are coupled to the second substrate, which is then coupled to the shielding base 110. The plurality of package leads 128 are also coupled to the second shielding base 110. The first plurality of conductors 124 and the second plurality
30 of conductors 126 electrically connect to the first plurality of circuit die 116 into the second plurality of circuit die 118, respectively. The first plurality of

conductors 124 and the second plurality of conductors 126 are electrically connected to the plurality of package leads 128.

5 Referring next to Fig. 2, the integrated circuit device package of Fig. 1 is shown after the layers have been assembled is illustrated.

 Shown is the radiation shielding lid 102, the first
10 layer 104, the second layer 106, the first shielding base 108, the second shielding base 110, the first substrate 112, the second substrate 114, the first plurality of circuit die 116, the second plurality of circuit die 118, the first circuit package 120, the second circuit package
15 122, the first plurality of conductors 124, the second plurality of conductors 126, the plurality of package leads 128 and a plurality of solder balls 130.

 The radiation shielding lid 102 is coupled to the
20 first circuit package 120. The first shielding base 108 is also coupled to the first circuit package 120 forming a cavity for the first substrate 112 and the first plurality of circuit die 116. The first plurality of circuit die 116 are coupled to the first substrate 112 which is coupled to
25 the first shielding base 108. The first shielding base 108 is then coupled to the second circuit package 122. The plurality of solder balls 130 are used to bind the first circuit package 120 to the second circuit package 122. The second shielding base 110 is coupled to the second circuit
30 package 122 forming a cavity for the second substrate 114 and the second plurality of circuit die 118. The second plurality of circuit die 118 are coupled to the second

substrate 114 which is coupled to the second shielding base 110. The plurality of package leads 128 are also coupled to the second shielding base 110. The first plurality of conductors 124 and the second plurality of conductors 126
5 electrically connect to the first plurality of circuit die 116 and the second plurality of circuit die 118, respectively. The first plurality of conductors 124 and the second plurality of conductors 126 also are electrically connected to the plurality of package leads
10 128.

By stacking multiple layers, such as the first layer 104 and the second layer 106 together to form the integrated circuit device package, the area on the circuit
15 board occupied by the integrated circuit device package is greatly reduced as compared to a package having only one layer. The weight of the package is also greatly reduced because the amount of material used for the radiation shielding lid 102, the first shielding base 108 and the
20 second shielding base 110 is reduced, for example by 30%. The weight of the package is reduced by reducing the amount of shielding material used for the same number of integrated circuits. Advantageously, the amount of material can be reduced while still providing the same or
25 comparable amount of shielding that is necessary for the integrated circuit device. An example of the reduction of shielding material is given below. The material used for the radiation shielding lid 102, the first shielding base 108 and the second shielding base 110 can be very dense,
30 thus a 30% weight reduction is very significant to the overall weight reduction of the package. The percentage of weight reduction may be different in every design and the

present invention should not be limited by a certain percentage of weight reduction.

As described above, the weight of a multi-layered integrated circuit package can be reduced by reducing the amount shielding material used for the integrated circuit device package. For example, a single layer device which is 4 inches by 4 inches could be packaged in a 4 layer device which measures $1\frac{1}{2}$ inches by $1\frac{1}{2}$ inches. This greatly reduces the amount of shielding material required even when using the same thickness for the radiation shielding lid 102 and the second radiation shielding base 110. For example, a single layer device would have two surfaces that required shielding material, the top and the bottom. Each surface would have an area of 16 square inches (4 inches X 4 inches). Thus, the total amount of shielding material would be 32 square inches (16 square inches + 16 square inches). For the 4 layer device, 5 surfaces would require shielding material (the base, the lid, and three surfaces acting as both a base and a lid of an adjacent layers). Each surface would be 2.25 square inches (1.5 inches X 1.5 inches). Thus, the total amount of shielding material for the 4 layer device would be 11.25 square inches (2.25 square inches X 5). Thus, the total amount of savings is 20.75 square inches of shielding material (32 square inches - 11.25 square inches).

The weight of the package can be further reduced by placing more sensitive circuit parts in the inner layers of the package. This provides the more sensitive circuit parts with increased shielding as radiation must pass through multiple layers of shielding material before

reaching the circuit die. This allows for thinner shielding layers throughout the package and thus reduces the weight of the package. The inner layers of the multi-layered device can be reduced in thickness because of the cumulative effects of the shielding material on the radiation. The shielding material acts in a cumulative way in stopping radiation from traveling through it. The inner layers may be thinner because the integrated circuit die located on the inner layers already has a large amount of shielding provided by the lid and base. Thus, the inner layers simply provide even more shielding. As much of the radiation has already been stopped by the lid or base, only a thin layer may be required to shield the integrated circuit die located on the inner layers from an amount of radiation greater than the total dose tolerance of the integrated circuit die. While this does not reduce the area of the shielding layers it does further reduce the weight of the multi-layered package.

In addition to reducing the weight of the package, the shielding package of the present invention is much more reliable as compared to a single layer multi-chip module. In a single layer device, the top and bottom of the device must provide enough shielding for the most sensitive circuit die in the package. Thus, the entire package must have a thick enough lid 102 and base 110 to protect the most sensitive circuit die from radiation. This prevents the most sensitive circuit die from receiving an amount of radiation greater than the total dose tolerance of the most sensitive circuit die. Thus, a single layer package can have more shielding material in the lid and base as compared to a multi-layered device which can place the more

sensitive circuit die on the inner layers, thus providing it with multiple layers of shielding. As the amount of shielding material in the lid 102 increases, for example, the ability to achieve a hermetic seal between the lid 102 and the first circuit package 120 decreases. This is because the lid 102 functions as a heat sink which interferes with the solder re-flow process used to attach the lid 102 to the first circuit package 120. As a result, the hermeticity of the package may be compromised because the lid will not properly solder to the first circuit package. As described above, if the hermeticity of the package is compromised, moisture or other chemicals may come in contact with the integrated circuit die and cause it to fail or otherwise become unreliable. Thus, a multi-layer device will be much more reliable than a single layer device as the hermeticity of the package is much less likely to be compromised.

Thus, because the integrated circuit package device of the present invention can use the combined shielding effects of the multiple layers to shield the most sensitive integrated circuit die within the integrated circuit package, i.e., the radiation shielding lid 102, the first shielding base 108 and the second shielding base 110, the thickness of the radiation shielding lid 102, the first shielding base 108 and the second shielding base 110 can be much thinner than that of the lid of a single layer device, therefore reducing the problem of achieving a hermetic seal as the lid will properly solder to the integrated circuit package. This achieves a highly reliable integrated circuit package device in accordance with the present invention.

Another problem with increasing the thickness of the radiation shielding of a single layer device (to provide a sufficient amount of shielding) is the radiation shielding lid is made from a very dense material which attaches to the ceramic package. When the radiation shielding lid is very thick it tends to crack the ceramic package and the ability to achieve a hermetic seal is greatly decreased. When the radiation shielding lid is very thick, as the shielding material expands and contracts with changes in temperature, it exerts a large amount of force on the ceramic packaging that can cause cracks in the ceramic packaging and thus failure of the hermetic seal. The more material that is used for the lid, the more force will be put on the ceramic packaging. Therefore, by providing a multi-layer device, the present invention eliminates the need to have very thick layers for any of the radiation shielding lid 102, the first shielding base 108 and the second shielding base 110, as the cumulative effect of the radiation shielding lid 102, the first shielding base 108 and the second shielding base 110 will shield the most sensitive circuit die by placing it on one of the inner layers of the package. This reduction in the thickness of the radiation shielding lid 102, the first shielding base 108 and the second shielding base 110 reduces the pressure on the ceramic packaging and reduces the likelihood the ceramic package will crack causing a failure of the device and failure of the hermetic seal.

In order to fit a large number of integrated circuit die into a single layer device, the area on the circuit board the device occupies must be substantially larger than

the multi-layered device of the present invention. This is because each integrated circuit die needs a certain amount of space to attach to the substrate. If there are multiple substrates stacked on top of each other, each substrate can
5 be smaller than a single substrate as in a single layer device and still provide enough of an area to attach all of the integrated circuit die. Thus, the overall area of the integrated circuit device package is reduced. Thus the embodiments provide for an integrated circuit device
10 package which takes up less area on a circuit board.

In addition to taking up less space on a circuit board the reduction in size also reduces the length of the each side of the multi-layered device as compared to a
15 single layer device having the same number of integrated circuit die. As the length of each side of the multi-layered device decreases, the ability to obtain a hermetic seal between the integrated circuit package and the radiation shielding lid 102 increases exponentially. This
20 is due to the properties of the integrated circuit package and the radiation shielding lid 102. The integrated circuit package is generally made from a ceramic material. Ceramic warps at a rate of 3 mils/inch, thus as the length of the side increases, the ability to ensure a hermetic
25 seal decreases exponentially. Thus, the larger the package, the lower the manufacturing yields will be and the more the part will fail. Thus, by having a multi-layered device, the length of the sides of the package is greatly reduced creating a much more reliable package.

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In one embodiment of the present invention the first layer 104 is comprised of the first radiation shielding

base 108, the first circuit package 120, the first substrate 112, and the first plurality of circuit die 116. The second layer 106 is comprised of the second radiation shielding base 110, the second circuit package 122, the second substrate 114, and the second plurality of circuit die 118. Advantageously, as shown in Fig. 2, the bottom of the first layer 104 forms a lid for the second layer 106. The first radiation shielding base 110 then acts to shield the second plurality of circuit die 118 from radiation. Advantageously, additional layers could be easily added to the shielding package. Thus, the present invention can easily be manufactured with more than two layers. If an additional layer is desired, another layer which is the same as the first layer 104 is put on top of the first layer 104. The additional layer will have a base which will act as the top of the first layer. The radiation shielding lid will then be placed on the additional layer, forming the top of the entire package, now having three layers. When two or more layers are present, the radiation shielding base 322 is coupled to the top-most layer, e.g., in Fig. 2 the first layer 104. Additionally, the plurality of package leads 128 are then coupled to the bottom-most layer, e.g., in Fig. 2 the second layer 106. Alternatively, the plurality of package leads 128 could be coupled to a different layer.

The radiation shielding lid 102, the first shielding base 108 and the second shielding base 110 shield the first plurality of circuit die 116 and the second plurality of circuit die 118 from radiation. The radiation shielding lid 102, the first shielding base 108 and the second shielding base 110 are designed such that the first

plurality of circuit die 116 and the second plurality of circuit die 118 are not exposed to an amount of radiation greater than the total dose tolerances of the first plurality of circuit die 116 and the second plurality of circuit die 118. Such design is achieved by determining a thickness of the radiation shielding lid 102, the first shielding base 108, and the second shielding base 110, based on the material selected for the radiation shielding lid 102, the first shielding base 108, and the second shielding base 110, the space (or other radiation) environment in which the integrated circuit device package is to be used, and the total dose tolerance of each of the integrated circuit die to be shielded.

Referring next to Fig. 3, a method for determining the material and thicknesses of the radiation shielding lid 102, the first shielding base 108 and the second shielding base 110 is shown. First, the total dose tolerances of the first plurality of circuit die 116 and the second plurality of circuit die 118 are determined 900. This test can be accomplished by a Cobalt-60 source or other penetrating irradiation source. Without the knowledge of what the inherent radiation tolerance is for the individual semiconductor device, the designer does not know how much or whether shielding is necessary.

Second, the radiation environment to which the first plurality of circuit die 116 and the second plurality of circuit die 118 will be exposed to is determined 902. This involves determining the radiation spectrum and dose depth curve of the particular mission or radiation requirement of the application. For orbits around the earth, this is

calculated using conventional radiation transport codes in
conjunction with conventional radiation spectrum tables.
Alternatively, any known radiation environment can be
modeled and subsequently a dose depth curve created for the
5 modeled environment.

The next step 904 involves determining the thickness
and material of the radiation shielding lid 102, the first
shielding base 108 and the second shielding base 110 such
10 that the first plurality of circuit die 116 and the second
plurality of circuit die 118 will not be exposed in the
determined radiation environment to an amount of radiation
greater than the total dose tolerances of the first
plurality of circuit die 116 and the second plurality of
15 circuit die 118. Once you know the total dose tolerances
of the first plurality of circuit die 116 and the second
plurality of circuit die 118 and the dose depth curve of
the radiation environment, the amount of shielding required
can be determined to bring the first plurality of circuit
20 die 116 and the second plurality of circuit die 118 within
the tolerance. Thus, the radiation shielding lid 102, the
first shielding base 108 and the second shielding base 110
are designed to be of a sufficient thickness to shield the
first plurality of circuit die 116 and the second plurality
25 of circuit die 118 from an amount of radiation greater than
the total dose tolerances of the first plurality of circuit
die 116 and the second plurality of circuit die 118. A
suitable process for determining shielding thickness in
accordance with the present embodiment is described in U.S.
30 Patent No. 6,261,508, of Featherby et al., for a METHOD FOR
MAKING A SHIELDING COMPOSITION, incorporated herein by
reference as if set forth in its entirety.

Another method in accordance with the present invention involves using the above mentioned modeling code to generate a dose versus depth curve in which the amount of shielding required to bring the total dose level under the first plurality of circuit die 116 and the second plurality of circuit die 118 total dose tolerance levels is determined. The package shielding is then analyzed by comparing the amount of radiation from all directions and the amount of shielding that is supplied from each of those directions. The radiation at the first plurality of circuit die 116 and the second plurality of circuit die 118 level is the summation of all the different angles normalized for the package area.

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Advantageously, the radiation shielding lid 102, the first shielding base 108 and the second shielding base 110 can be formed from a high Z material such as osmium, iridium, platinum, tantalum, gold, and tungsten. In general, any high Z material may be employed having an atomic number of 50 and above. More preferably, the range of atomic numbers can be between 60 and 100, inclusive. The most preferred range of atomic numbers is between 73 and 79, inclusive.

25

Alternatively, the radiation shielding lid 102, the first shielding base 108 and the second shielding base 110 can be made from a multiple layer shielding composition comprising a high Z layer and a low Z layer.

Advantageously, the radiation shielding lid 102, the first shielding base 108 and the second shielding base 110 can be made from a multiple layer shielding composition comprising

a high Z layer interposed between an outer low Z layer and an inner low Z layer. This configuration is an optimal shielding geometry for a geosynchronous orbit. The high Z layer is effective in stopping electrons and Bremsstrahlung radiation, while the low Z material is more effective in stopping protons. A geosynchronous orbit is dominated by trapped electrons, so it is preferable that the high Z layer is thicker than the two low Z layers.

The low Z layer is preferably selected from the group consisting of copper, nickel, carbon, titanium, chromium, cobalt, boron, silicon, iron and nitrogen. In general, any suitable low Z material may be employed having an atomic number of 30 and below, but the most preferred low Z materials are selected from the group consisting of copper, nickel, carbon, iron, titanium, silicon, and nitrogen. This packaging is further described in U.S. Patent No. 6,262,362 B1, of Czjakowski et al., for RADIATION SHIELDING OF THREE DIMENSIONAL MULTI-CHIP MODULES, incorporated herein by reference as if set forth in its entirety. In one preferred embodiment, the radiation shielding lid 102, the first shielding base 108 and the second shielding base 110 are made from Copper-Tungsten.

In addition to acting as a radiation shield, the radiation shielding lid 102, the first shielding base 108 and the second shielding base 110 also act as a heat sink for the entire shielding package. This helps to prevent the first plurality of circuit die 116 and the second plurality of circuit die 118 from overheating and causing a failure of the first plurality of circuit die 116 or the

second plurality of circuit die 118. In an alternative embodiment, the package is designed for use as a high reliability part, such as in military or aviation applications. In this embodiment, the radiation shielding lid 102, the first shielding base 108 and the second shielding base 110 are primarily used to dissipate heat away from the package, thus allowing the circuit die to operate in accordance within the specified temperature range for the circuit die. In this embodiment, the radiation shielding lid 102, the first shielding base 108, and the second shielding base 110 are made from a thermally conductive material. In an embodiment where the package device is not exposed to a large amount of radiation, the radiation shielding lid 102, the first shielding base 108 and the second shielding base 110 need only be made from a thermally conductive material. The radiation shielding properties of the thermally conductive material need not be considered in an environment where radiation is not a concern.

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For example, one embodiment of the present invention includes a memory module containing twelve circuit die that operates at 15 watts. The present embodiment provides a high reliability part that can dissipate the heat generated by the memory module such that the circuit die can operate within a recommended temperature range. One example of this type of device is an SDRAM memory module. Using 256 megabit SDRAM die, a module can provide 500 megabits of memory per layer, thus allowing 500 megabits, 1 gigabit, 1.5 gigabits, and 2 gigabits by stacking one, two, three or four layers respectively, while not growing the circuit board space required. In the example of eeprom die, one,

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two, three, or four layers can provide 8 megabits, 16 megabits, 32 megabits, and 48 megabits of memory respectively. In general, the memory is doubled every two layers.

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The plurality of solder balls 130 interconnect the first layer 104 and the second layer 106. These connections are then electrically connected to the plurality of package leads 128. The first layer 104 and the second 106 layer shown in Fig. 1 and Fig. 2 are non-hermetic layers individually. When the package is put together the base of the first layer 104 is attached to a metalized surface of the second layer 106 using solder and thus forming a hermetic seal for the second layer 106. A lid is then attached to the first layer 104 in order to complete a hermetic seal for the first layer 104. This allows the second shielding base 110 to act as both a lid and a base for the two layers making the entire package considerably thinner as compared to a multi-layered device without the shared shielding layer.

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The first substrate 112 and the second substrate 114 can be either a high temperature cofired substrate, a low temperature cofired substrate or a thick film substrate. The first substrate 112 and the second substrate 114 are made from the same type of alumina, but the processing of each is different. In accordance with a preferred embodiment, the high temperature cofired substrate is used as it is the most robust of the three types of substrates.

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The first substrate 112 and the second substrate 114 are attached to the first layer 104 and the second layer

106 using cyanate ester. Alternatively, in applications which require a large amount of heat dissipation a silver glass or silver epoxy can be used in order to provide a more thermally conductive connection.

5

In a preferred embodiment, the first layer 104 and the second layer 106 are attached using a high temperature solder (Au/Sn). The first radiation shielding lid 102 is also attached using the high temperature solder in order to
10 have the same coefficient of thermal expansion. This prevents the package from experiencing traditional solder joint fatigue and cracking failure that other solders may experience. The high temperature solder withstands thermal cycling which prevents the failure of the solder joints of
15 the package. Alternatively, the package layers may be attached using a Pb/Sn alloy, solder wires or a conductive epoxy. However, in environments that may experience high mechanical strain, it is preferred to use the high temperature solder, as this will prevent failure of the
20 package.

In accordance with one embodiment of the present invention a seal ring (not shown), which is used to seal the radiation shielding lid 110 to the circuit package
25 can be adjusted in height. This provides for a means of adjusting the space within each layer. Advantageously, this feature can be used when a larger height is needed for the plurality of circuit die within each layer of the shielding device.

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Referring next to Fig. 4 a layered shielding package is shown designed to shield a plurality of electronic

circuit die mounted directly to a ceramic package from radiation.

Fig. 4 shows a first radiation shielding lid 302, a second radiation shielding lid 304, a first layer 306, a second layer 308, a shielding base 310, a first circuit die 312, a second circuit die 314, a first circuit package 316, a second circuit package 318, a first plurality of conductors 320, a second plurality of conductors 322, a plurality of package leads 324, and a plurality of solder balls 326.

The first radiation shielding lid 302 is coupled to the first circuit package 316 forming a cavity for the first circuit die 312. The first circuit die 312 is coupled to the first circuit package 316. The second shielding lid 304 is coupled to the second circuit package 318 forming a cavity for the second circuit die 314. The second circuit die 314 is coupled to the second circuit package 318. The shielding base 310 is then coupled to a bottom of the second circuit package 318. Additionally, the plurality of package leads 324 are also coupled to the shielding base 310. The first plurality of conductors 320 and the second plurality of conductors 322 electrically connect to the first circuit die 312 and the second circuit die 314, respectively. The first plurality of conductors 320 and the second plurality of conductors 322 also are electrically connected to the plurality of package leads 324. The plurality of solder balls 326 couple the first circuit package 316 to the second circuit package 318.

In one embodiment the first layer 306 is comprised of the first radiation shielding lid 302, the first circuit package 316, and the first circuit die 312. The second layer 308 is comprised of the second radiation shielding lid 304, the second circuit package 318, and the second circuit die 314. Advantageously, the second radiation shielding lid 304 of the second layer 308 forms a bottom shielding layer for the first circuit die 312 in the first layer 306. The radiation shielding base 310 then acts in combination with the second radiation shielding lid 304 to shield the second circuit die 314 from radiation. Advantageously, additional layers could be easily added to the shielding package. Thus, the present invention can easily be manufactured with more than two layers. When two or more layers are present the radiation shielding base 310 is coupled to the bottom most layer, e.g., in Fig. 3 the second layer 308. Additionally, the plurality of package leads 324 are then coupled to the bottom most layer, e.g., in Fig. 2 the second layer 106. Alternatively, the plurality of package leads 324 could be coupled to a different layer.

The first radiation shielding lid 302, the second radiation shielding lid 304, and the shielding base 306 are all high Z material or alternatively layers of high Z and low Z material as describe above with reference to Fig. 1 and Fig. 2. The first radiation shielding lid 302, the second radiation shielding lid 304, and the shielding base 306 have thicknesses chosen to shield the first circuit die 312 and the second circuit die 314 from radiation. The thicknesses are determined such that the first circuit die 312 and the second circuit die 314 are not exposed to an

amount of ionizing radiation greater than the total dose tolerances of the first circuit die 312 and the second circuit die 314. This process is described above with reference to Fig. 1 and Fig. 2.

5

The first layer 306 and the second layer 308 are hermetically sealed layers. This prevents moisture or other compounds and chemicals from coming in contact with the circuit die. This prevents failure of the circuit
10 device. For example, water can erode the circuit die or attract silver which can lead to a short in the circuit die. The present invention reduces the length of the hermetic seal as compared to a single layer device. This greatly increases the reliability of the hermetic seal and
15 prevents failure of the device.

Referring to Fig. 5 a multi-layer shielding package is shown for shielding a plurality of electronic circuit die mounted directly to a shielding layer.

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Fig. 5 shows a radiation shielding lid 402, a first layer 404, a second layer 406, a first shielding base 408, a second shielding base 410, a first circuit die 412, a second circuit die 414, a first circuit package 416, a
25 second circuit package 418, a first plurality of conductors 420, a second plurality of conductors 422, a plurality of package leads 424, and a plurality of solder balls 426.

Fig. 5 is similar in function and structure to Fig.
30 2. However, Fig. 5 shows a first circuit die 416 attached to the first radiation shielding base 408 and the second circuit die 418 attached to the second radiation shielding

base 410. The first layer 404 comprises the first circuit package 416, the first shielding base 408, the first circuit die 412, and the first plurality of conductors 420. The second layer 406 comprises the second circuit package 418, the second shielding base 410, the second circuit die 414, and the second plurality of conductors 422. Advantageously, the first radiation shielding base 408 acts as a lid for the second layer 406. Additionally, the radiation shielding lid 402 is coupled to the first layer 404 and the plurality of package leads 424 are coupled to the second layer 406. The plurality of solder balls 426 attaches the first layer 404 to the second layer 406.

Referring to Fig. 6 a layered shielding package designed is illustrated to shield from radiation a plurality of electronic circuit die mounted directly to a substrate.

Fig. 6 shows a first radiation shielding lid 502, a second radiation shielding lid 504, a first layer 506, a second layer 508, a shielding base 510, a first plurality of circuit die 512, a second plurality of circuit die 514, a first circuit package 516, a second circuit package 518, a first plurality of conductors 520, a second plurality of conductors 522, a plurality of package leads 524, a plurality of solder balls 526, a first substrate 528, and a second substrate 530.

Fig. 6 is similar in function and structure to Fig. 4. However, Fig. 6 shows the first substrate 528 and the second substrate 530 coupled to the first circuit package 516 and the second circuit package 518, respectively. The

first plurality of circuit die 514 and the second plurality of circuit die 516 are coupled to the first substrate and the second substrate 530, respectively.

5 Referring to Fig. 7 a layered shielding package is shown designed to shield from radiation a plurality of electronic circuit die mounted directly to a substrate.

10 Fig. 7 shows a first radiation shielding lid 602, a second radiation shielding lid 604, a first layer 606, a second layer 608, a shielding base 610, a first plurality of circuit die 612, a second plurality of circuit die 614, a first circuit package 616, a second circuit package 618, a plurality of package leads 624, a plurality of solder
15 balls 626, a first substrate 628, a second substrate 630, a first plurality of substrate solder balls 632 and a second plurality of substrate solder balls 634.

20 Fig. 7 is similar in function and structure to Fig. 6. However, Fig. 7 shows the first substrate 628 attached to the first circuit package 616 with the first plurality of solder balls 632. The second substrate 630 is attached to the second circuit package 618 with the second plurality of solder balls 634.

25

 Referring to Fig. 8 a layered shielding package is shown designed to shield from radiation a plurality of electronic circuit die mounted directly to a substrate.

30 Fig. 8 shows a first radiation shielding lid 702, a second radiation shielding lid 704, a first layer 706, a second layer 708, a shielding base 710, a first plurality

of circuit die 712, a second plurality of circuit die 714,
a first circuit package 716, a second circuit package 718,
a plurality of package leads 724, a plurality of solder
balls 726, a first substrate 728, a second substrate 730, a
5 first plurality of substrate solder balls 732 and a second
plurality of substrate solder balls 734.

The layered shielding package of Fig. 8 is similar
in function and structure to Fig. 7. However, Fig. 8
10 shows the second radiation shielding lid 704 acting as a
heat sink for the first layer 706. The second radiation
shielding lid 704 touches the first circuit package 716,
thus dissipating heat from the first layer 706. If the
device generates a large amount of heat, the second
15 radiation shielding lid 704 can be thermally coupled to
either the first radiation shielding lid 702 or the
shielding base 710.

In this embodiment, thermal vias, such as described
20 with reference to Fig. 9 can be used to thermally connect
the first radiation shielding lid 702, the second radiation
shielding lid 704 and the shielding base 710. The
shielding base 710 can then be connected to a large heat-
sink for the circuit board. Alternatively, the first
25 radiation shielding lid can be connected to the large heat
sink.

Additionally, each layer shown in Fig. 8 is
hermetic. Ceramic material is used for the first layer 706
30 and the second layer 708. Thus, no moisture is allowed
into the space containing the first plurality of circuit
die 712 and the second plurality of circuit die 714. This

prevents failure of the circuit die. If moisture were to come in contact with either of the first plurality of circuit die 712 and the second plurality of circuit die 714, the circuit may fail. Additionally, moisture can
5 induce the migration of silver from conductors or component terminations, which can result in a short circuit and device failure. During the manufacturing process the non-sealed package is exposed to a high temperature bake-out procedure to remove any moisture or residual gasses and is
10 then sealed.

Referring to Fig. 9 a package device is shown for dissipating heat from a multi-layered package containing a plurality of circuit die.

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Fig. 9 shows a lid 802, a first layer 804, a second layer 806, a first base 808, a second base 810, a first substrate 812, a second substrate 814, a first plurality of circuit die 816, a second plurality of circuit die 818, a
20 first circuit package 820, a second circuit package 822, a first plurality of conductors 824, a second plurality of conductors 826, a plurality of package leads 828, a plurality of solder balls 830, a first plurality of thermal vias 832, a second plurality of thermal vias 834 and a
25 plurality of thermal layer connectors 836.

The plurality of solder balls 330 is used to electrically connect the first plurality of circuit die 816 with the second plurality of circuit die 818.

30 Alternatively, a plurality of castellations are used to connect the first plurality of circuit die 816 and the second plurality of circuit die 818, however, in

applications which require a high circuit density, the plurality of solder balls is preferred.

The first plurality of thermal vias 832 and the
5 second plurality of thermal vias 834 are fed through the
first substrate 812 and the second substrate 814
respectively. Advantageously, the first plurality of
thermal vias 832 and the second plurality of thermal vias
834 are connected to the first plurality of circuit die 816
10 and the second plurality of circuit die 818 respectively.
They are then fed through the first substrate 812 and the
second substrate 814 and connected to one or more of the
lid 802, the first base 808 and the second base 810. The
lid 802, the first base 808 and the second base 810 can
15 also be interconnected through the thermal layer connectors
836. In this embodiment, the second base acts as the
principle heat sink and can be attached to a system heat
sink. This allows for heat to dissipate from the first
plurality of circuit die 816 and the second plurality of
20 circuit die 818. The plurality of thermal layer connectors
836 connects the first plurality of thermal vias 832 and
the second plurality of thermal vias 834 to the second base
810 which acts as a heat sink for the entire package. When
used in a system which has a large system heat sink, the
25 second shielding base 810 could be connected to the large
system heat sink. Advantageously, the thermal vias could
be utilized in any of the previously disclosed embodiments.

In one embodiment, the package device operates as a
30 memory module. Thus, the device is capable of containing
large amounts of memory in a relatively small space. The
design of the package allows for the dissipation of the

large amount of heat generated by the plurality of circuit die.

The heat sink feature of the present invention can also be utilized in a space environment. Providing the circuit die with a good heat sink is very important in a space environment to ensure the reliability of the part. In a space environment there is the additional problem of having no airflow over the device in order to help control the heat. Thus, having a good heat sink is very can be very important in preventing a circuit die from operating within a given temperature range of the circuit die.

In accordance with the embodiments of Figs. 1-9, electrical redundancy can be built into the multi-layered package. For example, redundant electronic circuit die can be placed on different layers of the multi-layer package. Thus, if one of the layers fails because of hermetic seal failure, temperature failure, mechanical failure, or radiation failure the backup device will still be operable. This prevents failure of the entire package. In one example a circuit die on the top layer may fail do to an unexpected amount of radiation, however, the redundant circuit die on the second layer would not fail because of the extra layer of shielding.

Additionally, the embodiment shown in Figs. 1-9 allow for a device which has a fully traceable circuit die. Different lots of circuit die has different radiation shielding tolerance, thus by having a device which can be traced by lot allows for a high reliability part. If one of the circuit die fail, it can be traced back to the

manufacture and all the other parts with circuit die from the same lot can be located.

Referring next to Fig. 10, a method is shown for making a highly reliable layered electronic circuit device in accordance with the present invention. The method described can be used for making the embodiments shown and described with reference to Figs. 1-9.

First, a first package layer is formed 1000. Next, a second package layer is formed 1002. The first package layer and the second package layer are described herein with reference to Figs. 1-9. In general the first package layer and the second package layer include a circuit package, a radiation shielding base or a radiation shielding lid coupled to the circuit package, and a circuit die. In some embodiments, the first package layer and the second package layer can include a plurality of circuit die coupled to a substrate. Additionally, the first package layer and the second package layer can include a plurality of conductors coupled to the circuit die.

Next, the first package layer is coupled to the second package layer 1004. In some embodiments the base of the first package layer acts as a lid for the second package layer. It should be understood, in accordance with the method described that more package layers could be coupled together to accommodate a larger number of circuit die. For example, if the first package layer and the second package layer include a circuit package, a radiation shielding base and a circuit die, then a similar third package layer could be coupled to the second layer. The

base of the second package layer could then act as a lid for the third package layer. If more layers are desired, they can be added on in a similar fashion. Similarly, for example, if the first package layer and the second package layer include a circuit package, a radiation shielding lid and a circuit die, then a similar third package layer could be coupled to the first package layer. If more layers are desired, they can be added on top of the third package layer.

10

The next step involves coupled a lid or a base to either the first package layer or the second package layer respectively 1006. If the first package layer and the second package layer are formed with a radiation shielding base, then a lid will be coupled to the first package layer. Alternatively, if the first package layer and the second package layer are formed with a radiation shielding lid, then a base will be coupled to the second package layer.

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While the invention herein disclosed has been described by means of specific embodiments and applications thereof, other modifications, variations, and arrangements of the present invention may be made in accordance with the above teachings other than as specifically described to practice the invention within the spirit and scope defined by the following claims.

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